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ABSTRACT

This report describes the Palenque Project, a highly interactive, multimedia, optical disc research prototype which was developed for home use and tested by observing 25 children in the 9 to 14 year age range and their families and 8 12-year-olds in pairs. It is noted that the project was intended to create a rich, multimedia database environment for children and their families that would pique their curiosity and foster self-guided exploration, information seeking, and decision making as they explore a Mayan ruin in the Yucatan called Palenque. Following an overview of the project and a description of the design and development team, the report provides descriptions of: (1) the components of the prototype design; (2) the target audience and context for use; and (3) the two phases of design, development, and research which produced the preliminary and final prototypes. It is noted that the research and development project involved concurrent and iterative processes of design, research, production, and programming over the course of a 2-year time frame. It is further noted that since the final goal was to produce research prototypes rather than products, collective research efforts in the development of design conventions that reflected chosen pedagogical biases in content and theme development, interface design, production techniques, and technical implementation, were the essence of the project rather than by-products or activities conducted after product completion. (8 references) (GL)

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Kathleen S. Wilson and William J. Tally

Technical Report No. 47

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THE PALENQUE PROJECT: A PROCESS OF DESIGN AND DEVELOPMENT AS RESEARCH IN THE EVOLUTION OF AN OPTICAL DISC PROTOTYPE FOR CHILDREN*

Kathleen S. Wilson and William J. Tally

OVERVIEW OF THE PALENQUE PROJECT

The Palenque Project has been a collaborative effort between Bank Street College of Education (BSC) in New York City and the David Sarnoff Research Center, Inc. (DSRC, formerly GE/RCA, Labs) in Princeton, New Jersey. The primary goal of the project was to create an interactive, optical disc prototype for children to use with their families at home--a prototype based on Bank Street's *The Second Voyage of the Mimi* television show, which demonstrates some of the unique features of GE's digital video interactive (DVI) technology.

The project has involved a number of research directions, both educational and technical, since its inception in 1985. In fact, as the title of this paper implies, both the design and the development (production and programming) of the Palenque prototype were conceived of as exploratory research efforts. In terms of pedagogy and interface design, we were guided by several of the biases that are at the heart of much of the research and educational product development work at Bank Street College. These include a concern that learning be an active enterprise guided by children's interests and curiosity, which takes into account their actual experience of the world, and a commitment to formative, as opposed to summative, research in the design of new materials.

Thus, we tried to create a rich, multimedia database environment for children and their families that would pique curiosity and foster self-guided exploration, information seeking, and decision making. The Palenque prototype allows children to explore a Maya ruin in the Yucatan, called Palenque, by literally "walking around" it through a virtual travel experience, and by conceptually exploring information presented in a multimedia "Museum" database. We attempted to design an experience that would allow children to browse freely, make choices about what to see, when, and where, and to discover things along the way as they explore. We undertook a series of formative research efforts, at the same time observing children using the prototype as it evolved to help inform our ongoing design decisions about issues of appeal and comprehensibility.

In terms of production, programming, and technical research, we used the Palenque prototype as a vehicle for developing and testing a highly interactive, opti-

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The Palenque project was funded by the David Sarnoff Research Center, Inc., Princeton, NJ (formerly GE/RCA Labs).

Project contributors include: John Borden, Samuel Gibbon, Donna Goldstein, Joana Hattery, Jenny Howland, Richard Hendrick, Robert Mohl, Marcia Perskie, Richard Ruopp, Jeffrey Strange, George Stuart, William Tally, and Kathleen Wilson for Bank Street College; and Thomas Craver, Holly Faubel, Jesse Kapili, Richard Levine, Sandra Morris, David Ripley, and Paula Zimmerman for the David Sarnoff Research Center.

cal disc prototype that demonstrates a variety of design concepts, filming techniques, and programming innovations. Our collaboration with the David Sarnoff Research Center, Inc., the funder of the Palenque Project, allowed us to experiment with state-of-the-art optical disc (videodisc and CD-ROM), digital audio and motion video (DVI [Digital Video Interactive] was introduced by GE/RCA in 1987), high resolution color graphics, and computing technology. We attempted to incorporate into the design of Palenque as many of the available advanced features of this technology as possible given the time, money, and human resources available to us.

THE PALENQUE DESIGN AND DEVELOPMENT TEAM

The Palenque design and development team incorporated a variety of people with diverse backgrounds and affiliations for the various stages of prototype development. A core staff from both Bank Street College and the David Sarnoff Research Center worked on Palenque consistently since its inception, although only two people, one from Bank Street College (the director of design and research/ producer) and one from the David Sarnoff Research Center (the main programmer) worked on Palenque as a full-time effort throughout the project. Experts and outside companies, such as Peace River Films of Cambridge, Massachusetts were subcontracted as needed.

Since Palenque has been a truly collaborative effort between BSC and DSRC, both organizations were involved in all aspects of the project. Major responsibilities can be roughly categorized as follows: BSC was responsible for design (treatments, design documents, scripts, video storyboards, screen designs, user walk throughs, interface design, software storyboards), production (video, film, stills, sound effects, audio narration), content research, and formative evaluation with child users; DSRC was responsible for film transfers, post-production, digitizing, disc mastering, graphics creation, and programming.

Major project roles have included: Bank Street College staff: Director of Design and Research/Producer; Research Coordinator and Design Assistant; Research and Design Assistant; Research Assistant; Director of Photography; Associate Producer/Sound Recordist; Photographers; Production Assistant; Mexican Production Coordinator; Talent; Consultants--Technical, Script, Content; Advisors--Creative and Financial; Voyage of the Mimi Productions. David Sarnoff Research Center staff: DSRC Project Leader; two Programmers; Post-production Coordinator; Graphic Artist; Digitizing, Film Transfer, Editing Staff; Software Technology Research Group; Microsystems Software Research.

PALENQUE PROTOTYPE DESIGN DESCRIPTION

The Palenque optical disc prototype (Wilson, 1987) is based on themes, locations, and characters from *The Second Voyage of the Mimi* television show, which is being produced at Bank Street College. In the TV show, a cast of scientists and children explore the Yucatan's Maya ruins and are introduced to ancient Maya culture, archeology, and related sciences. Our Palenque prototype incorporates this theme to the extent that the user's experience is based on a virtual travel exploration of the ancient Maya site, Palenque, and on the perusal of a multimedia Palenque "Museum" database.

Rather than being explicitly structured as tutorial sequences or directed activities and games, the information in Palenque is implicitly structured to allow for user-directed exploratory "experiences." One of our design goals was to create an in-

teresting visual, auditory, and textual database environment in which information in many formats could be browsed spatially and thematically by children. In addition, we experimented with visual menus, the use of pictographic icons, and window-based interface conventions that might make navigation around the disc motivating and comprehensible for young users.

There are six basic components to the Palenque Prototype:

1. VIDEO OVERVIEWS are used to introduce the prototype and the three major modes of Palenque: Explore, Museum, and Game.

2. EXPLORE MODE involves a virtual travel experience, which encourages exploration and open-ended discovery by allowing users to "walk" or "run" around the archeological site at Palenque. Users indicate with a joystick in which direction they would like to travel and which places they would like to visit. Information "zooms" into places of interest, 360-degree pans and tilts, and a dynamic you-are-here map all complement the "walking" feature of Explore Mode. Thus, in this component of Palenque the information is stored and accessed spatially, so that users must "walk" to locations on the site to learn more about them.

3. MUSEUM MODE is a multimedia database of information relevant to the Palenque site. The information includes text, still photographs, drawings, motion video, graphics, sound effects, and audio narration. Users browse through virtual theme "rooms" to learn more about such things as Maya glyphs and the tropical rainforest. In the museum, information is hierarchically structured and accessed thematically so that users can browse through categories of information presented in greater or lesser detail, as desired.

4. THREE CHARACTERS are incorporated into the Palenque prototype: a young teenager and a female archeologist from Bank Street's *The Second Voyage of the Mimi* TV show, and an archeologist from National Geographic who specializes in Maya studies. These characters serve as companions, guides, and content experts.

5. SIMULATED TOOLS are available to users to help in the exploration of the Palenque site and museum. These include a camera, an album, a compass, a tape recorder, and a magic flashlight. The magic flashlight allows users to "see" buildings as they looked before reconstruction began or in the days of the ancient Maya.

6. GAMES AND ACTIVITIES are available in the museum theme rooms, such as putting back together fragmented glyphs and constructing one's own jungle symphony.

TARGET AUDIENCE AND CONTEXT FOR USE

Palenque has been designed for use by children in the 8 to 14 year age range at home with their families, rather than for use in classrooms. The age range for the children in our target audience was determined by the target audience for Bank Street's *The Second Voyage of the Mimi* materials. With a nonschool learning environment in mind such as the home, we experimented with intuitively accessible interface conventions in an attempt to create an interactive experience that would be easy to learn to use, appealing, and comprehensible to a wide variety of users. We suspended the typical trade-off between "education" and "entertainment"; instead, we tried to create an inherently motivating environment that would be both informative and fun for family members of all ages.

THE CONCURRENT PROCESSES OF DESIGN AND DEVELOPMENT AS RESEARCH

A traditional instructional design sequence usually involves a process that begins with needs assessment and the generation of goals, proceeds through design, production, and programming, and concludes with a summative evaluation. Due largely to the experimental nature of our project, we, on the other hand, simultaneously experimented with several ongoing efforts, each informing the other--a process similar in some ways to the rapid prototyping and iterative design process described by Brown (1986). These parallel and iterative efforts included research (formative evaluation with children, content research, production experiments, and technical experiments with evolving DVI technology), design (treatments, scripts, and storyboards), production (filming in Mexico and studio production in the United States, as well as post-production and mastering), and programming.

Although the role of evaluation in the design of most instructional optical discs is summative in nature, we pursued a series of ongoing formative research studies as the Palenque prototype evolved. As we proceeded through preliminary "pink" discs, three videodisc prototypes, a CD-ROM-based prototype, and many versions of accompanying software, we observed children using them for issues of appeal, comprehensibility, and ease of interaction. We studied such things as children's understanding of virtual travel and 360-degree user-controlled panoramic views, their use of spatial organizers, the ease and accessibility of our multimedia database and characters, and the effectiveness of a joystick as an input device. The results of these ongoing observational studies led to changes in the evolving design, which were implemented in each successive disc and software prototype.

PHASES OF DESIGN, DEVELOPMENT, AND RESEARCH

The Palenque project included two phases of work over a 2-year period, from September 1985 through September 1987. We began with an initial period of preproject negotiations from April through August of 1985. In phase I--September 1985 through January 1986--we developed a preliminary Palenque prototype for testing with children. In phase II--February 1986 through September 1987--we developed a final Palenque prototype through parallel design, development, and research efforts.

Phase 1: Preliminary Palenque Prototype Development

Parallel design, research, production, and programming efforts were under way as we developed our preliminary prototype during phase I of the Palenque project. Our research efforts included design research (content research, reviews of existing design conventions, a review of related BSC research, and preproduction formative evaluation) and formative evaluation of the preliminary Palenque prototype. Our production and programming efforts included a scouting trip to Palenque, the development of a videodisc prototype, and the creation of a library and map database program prototype. Our design efforts included the creation of a final treatment and preliminary design document for the final Palenque prototype, based on the results of our research, production, and programming efforts. We will limit our discussion here to the formative research efforts we pursued, rather than discussing all of our design, production, and programming experiments.

Our design and research activities overlapped in so many ways that, as the Palenque project progressed, the designers became more and more involved in the research and vice versa. In essence, the feedback loop evolved into an exchange between the designer/producer/researcher team and the programming team, rather than among four separate teams: researcher, designer, producer, programmer. This was largely because of the small size of the staff and the consequent necessity of each person's wearing many hats. For example, the Director of Design was also the Producer and the Director of Research; the Research Coordinator was also a Design and Production Assistant; one of the programmers was a still photographer for the first Palenque location filming.

Content Research

Background research on such topics as the ancient Maya, the Yucatan, rainforests, archeology, Maya glyphs, and early explorers to the Yucatan was conducted at Bank Street for the *Mimi* project (Howland & Seidel, 1985) and was used by the staff of the Palenque project as needed. In addition, library research, museum visits, a scouting trip to Palenque, and consultation with various content specialists all contributed to decisions made concerning appropriate content and themes to include, given our target audience and home context.

Review of Existing Design Conventions

Products similar to our proposed Palenque prototype in either theme, technology, or format were collected for analysis. These included board games with archeology themes; books for children with Maya themes, such as the *Choose Your Own Adventure* mysteries; videotapes and films with Maya themes; computer software with archeology themes, visual databases, or exploration and adventure formats; and videodiscs with surrogate travel formats, visual menu structures, and Maya themes.

Review of Previous Related Bank Street College Work

Three previous research projects conducted at BSC's Center for Children and Technology were reviewed: the formative evaluation study for *The Second Voyage of the Mimi* (Howland & Seidel, 1985); a study of children using database software in classrooms (Freeman, Hawkins, & Char, 1984); and the *Mimi I* videodisc prototype and formative research project (Wilson, 1985). Relevant findings from these projects were incorporated into our evolving Palenque prototype design. For example, the *Mimi* formative research provided information about the knowledge, attitudes, and interests of 8- to 14-year-old children concerning such topics as Maya glyphs, exploring ruins, dating artifacts, and Palenque.

Review of previous BSC research with children using database software in classroom contexts also yielded some interesting information for our Palenque design. We learned, for example, that children found traditional (DBMS) database management software, originally designed for business environments, difficult to use. The databases studied were text-based and required users to understand a large number of prompts. In addition, keyboard input required manipulation of different control keys, which was confusing. Children seemed to be more familiar with class discussions led by the teacher about topics of interest with visuals for support, such as films, maps, and photos. The conclusion of the study, put quite simply, was that existing text-based databases were not appropriate for children in classrooms.

Formative research conducted with children using Bank Street's *Mimi I* videodisc prototype led to several recommendations for future optical disc design. These recommendations were incorporated, to the extent possible, into the Palenque design. For example, the use of a videodisc as a multimedia database to be explored or browsed through was found to be appealing and understandable for children in the *Mimi* target audience. The use of nautical maps and timelines, as highly visual, "spatial menus," proved successful in motivating children's exploration of the disc contents. Superimposed pictographic icons (on video images) for ease of navigation around the disc environment were also easily mastered and clearly understood by young users. Computer-generated zooms and various special effects for transitions and conceptual highlighting added to the comprehensibility of various visual sequences. The high realism of the motion video sequences (e.g., characters and animals), sounds (e.g., songs and voices), ability to control motion video and audio segments, and the ease of use of the (keypad) input device were all found to be strengths of the videodisc design.

Preproduction Formative Evaluation

The preproduction research for the Palenque prototype involved two studies. In the first, children's concepts of time, maps, and spatial relationships were studied using paper maps, photographs, and print materials. In the second study, the understanding and appeal of Maya glyphs, bas-reliefs, and an on-camera archeologist were studied using photographs, replicas of glyphs, a videotape of an archeologist, and the narrated story of Palenque's great ruler, Pacal. These studies were formative in nature (Chen, Lieberman, & Paisley, 1985; Mielke & Chen, 1983; Tuckman, 1985) and, as such, were intended to inform evolving design and development efforts rather than to discover or test hypotheses. For this reason, the sample sizes were small and most of the children were students at the same school--the Bank Street School for Children, a private school in New York City. The first study involved 15 children between the ages of 8 and 13; the second involved 19 children between the ages of 8 and 12. The children were seen in pairs for 50 minutes during which time they were interviewed and asked to do various tasks, while the researcher observed, took notes, and audiotaped the sessions for later reference.

From the first study, we discovered several things that were considered in our Palenque design discussions. First, most of the children had no sense of the time period of the ancient Maya, nor did they have a sense of the evolution of a site over time--its abandonment, ruin, overgrowth by the rainforest, eventual "discovery" and archeological restoration. In terms of spatial relationships, most children were adept at grasping the relationships between different views of the site; for example, recognizing the same structures from different angles and distances. Aerial views were found to be helpful orientation aids.

From the second study, we learned that children were interested in the story of Pacal--the 12-year-old ruler of Palenque during its heyday--who died and was buried in a sealed tomb inside the Temple of the Inscriptions. They also found the story of the discovery of the tomb in 1951 by Alberto Ruz very exciting. Carved panels showing people were more interesting to children than panels showing just glyphs, and they needed help recognizing the important elements of many glyph images. Children liked comparing elements in different representations of glyphs, and glyphs with recognizable objects--such as animals--were most appealing.

Prototyping: Production and Programming Research

Phase I development efforts included three experimental activities: (a) a scouting trip to Palenque in October 1985 to conduct experimental filming of virtual travel sequences, and to collect relevant still images for our multimedia database; (b) the creation of a prototype for our visual database (we used Filevision software for Apple's Macintosh computer, which allowed us to simulate several features of our proposed database, including a library metaphor and a dynamic Palenque map); and (c) the production and programming of our first Palenque videodisc prototype. For this last activity, we used a videodisc system which consisted of a Sony SMC-70 computer, Sony LDP 1000/A videodisc player, and a Sony color monitor.

Formative Evaluation: Two studies

Two formative evaluation studies were conducted during phase I of the Palenque project: One involved observing children using the visual database prototype; the other involved observing children using the virtual travel videodisc prototype described above. These prototypes were designed to simulate different features of our final Palenque prototype. For this reason, the research results from observations of children using these prototypes were very helpful in guiding our design decisions. As with the preproduction formative studies, the sample sizes were small--10 children for the first study and 22 for the second. Some of the children were students at the Bank Street School for Children; others attended a public school in East Harlem. The children ranged in age from 9 to 14. During each session, they were interviewed and observed in pairs. We decided to observe pairs rather than individual children because we felt we would learn more about their thoughts while using the system if they were able to verbalize them to a peer. Also, we felt that pairs or small groups would be a likely pattern for use in a typical home setting. For the database study, children were observed for one 50-minute session. For the videodisc prototype study, children were observed for either two 45-minute sessions or one 45-minute session. Researchers took notes and audiotaped each session.

The first phase I formative study: A visual database. The main research questions for the visual database study were: Can children make use of the range of options available? How appealing is it to move around a visual database structured as a library with different "rooms" and a dynamic map of the Palenque site? How appealing is the content of the database? Some of the children's comments were as follows:

> "It's not a game, it's more like a quest. You go into different rooms and find information about things."
>
> "Ooh fresh! We're IN this room! Did you make this picture?"
>
> "It was fun seeing the computer picture change into something different. You get a whole new room and say, 'Hey neat, what can we discover here?'"

In general, we found that the children were engaged by both the content and the visual nature of the Filevision program, as well as by the capabilities of the technology. The idea of finding, exploring, and revealing embedded or "hidden" text and images was especially appealing. The most attractive features of the dynamic map were the temples and the rainforest. The realism of the reference room template was very appealing because it was more than "just words." Children did not recognize the main template as a "library," since libraries are seen as places for books. There-

fore, we changed the allusion from library to museum. We also included color in our final map.

The second phase1 formative study: A videodisc prototype. The main research questions for the videodisc prototype study were: Do children feel as though they are "in" the surrogate travel space and "moving through" it, rather than simply viewing a succession of still images? Do spatial organizers, such as a person marking an intersection or leading the way on a jungle path, help children orient themselves? Do children understand a 360-degree pan as a rotated horizontal view with no forward or reverse movement through space? Do they know when they have rotated a complete 360 degrees versus 180 degrees? Do they get any meaningful information from the pan? Some of the children's comments were as follows:

> "Neat...it feels like you're a person walking around. Try to run. Whoa, we're RUNNING down this path (makes a sound like a motor). We're going to fall [off the bridge]--splash! Be careful, don't walk on the grass."
>
> "It's a way to see other parts of the world without going there . . . I wish I could go there . . . I feel like I've almost been there."

In general, we found that the novelty of self-directed movement around the Palenque sight was very appealing and engaging, as were the capabilities of the technology. Most children had a sense of location and movement around the site. Their comments indicated that the realism of the video images was an advantage, making exploration in and of itself very appealing. Simple search activities were eagerly pursued by the children. The most attractive locations on the site were the rainforest area and the Temple of the Inscriptions. The children liked "climbing" up the steps. Arrows controlling movement were the most frequently selected icons. The mime was salient both as a reinforcement to the travel arrows and as a landmark. Beyond this, children simply enjoyed seeing people on the site. These people often helped to establish a sense of scale and were thought to be good guides.

Some design conventions were observed to be less successful than others. These were revised and tested in subsequent versions of the Palenque prototype. For example, the simple forward and reverse arrows were often read as "up" and "down," not "forward" and "reverse." The 180-degree turn option was available only at selected spots, which was not often enough for the needs of our child explorers. Children did not select pans often and did not completely understand them. The resolution of the digitized and unwrapped fish-eye pans was quite low and the continuity of the still-frame pans was weak. The most appealing and understood pans were the motion video pans. In all cases, children wanted to control the pans.

Phase II:
Final Palenque Prototype Development

As in phase I, parallel design, research, production, and programming efforts were under way in phase II throughout our process of developing the final Palenque prototype. During phase II, our ongoing research efforts included content research, production and programming research, and formative evaluation. These efforts combined to inform the design of the prototype as it evolved through a series of revised videodisc and software prototypes, using a DVI simulation system before the completion of the CD-ROM-based DVI system in 1987.

The DVI simulation system used in phase II included a number of components, all chosen to simulate various features of the evolving DVI technology. The com-

ponents were an IBM PC-AT with extended memory; an AT&T Targa graphics board; a custom, digital audio board; an IBM monitor; a stereo, color RCA monitor; a Sony LDP 2000 videodisc player; and a Gravis 3-button joystick.

Prototyping: Production and Programming Research

The first two prototypes mastered in phase II were "pink" (check) discs. These were incomplete and temporary in many ways, but contained enough of the final images and sounds to allow for the programmers, designers, and formative researchers to proceed without having to wait for the final disc to be completely edited and transferred to one-inch tape for mastering. The first pink videodiscs and accompanying software included virtual travel paths and branches, joystick control, dynamic icons, 360-degree pans and tilts, the camera and album features, the menu bar and icon panel, and a preliminary museum menu. Each subsequent disc that was mastered and the accompanying software that was developed contained the same information as the previous versions, plus such additional information as the video overviews and museum theme rooms. Two additional videodiscs were mastered after the preliminary pink discs. In the winter of 1986/1987, DVI technology reached the final stages of development at the David Sarnoff Research Center. A preliminary CD-ROM based prototype of Palenque for use as a DVI (Digital Video Interactive) demonstration for GE/RCA was mastered early in 1987, with a second CD-ROM prototype mastered in the fall of 1987.

Formative Evaluation and Design Revisions

Each successive disc/software version of the Palenque prototype was used in formative research with children at Bank Street's Center for Children and Technology. A living room-like setting was created to provide a testing environment that felt more like a home than a classroom, since our intended context for Palenque was the home. We decided not to conduct any testing in actual homes because of the fragile and bulky nature of our DVI simulation system, which we felt could not withstand frequent moves. The observations made during our testing sessions led to ongoing design revisions that were storyboarded and then programmed in an ongoing feedback loop between researchers/designers and programmers.

Our research concerns were focused primarily on children's ability to use various interface conventions and on general issues of appeal and comprehensibility. In terms of the interface, we observed the ways in which children used the menu bar, icons, screen conventions, and joystick (for travel and for cursor control). Some of our questions were: How quickly did children learn the interface conventions? How easy was it for them to navigate through the system? How well did they seem to understand it?

In terms of appeal, we observed the degree to which using Palenque held children's attention and interest. Which components seemed to be most appealing (the virtual travel exploration; browsing through the multimedia museum database; interactive games; listening to characters)? Which content areas were of the most interest (the Palenque site with its ruins; the tropical rainforest; Maya glyphs)? Which media formats or combinations of formats were appealing (audio; text; motion video; still photographs)?

In terms of comprehensibility, we observed the ways in which children seemed to use the rich and often complex screens, the variety of interactive options, and the

thematic and spatial organizational structure. Are children getting anything meaningful from the Palenque experience? Can they make sense of and use the range of information and interactive features? Does the organization of the information in thematic and spatial structures make sense to them?

The first phase II formative evaluation study. For the first formative evaluation study in phase II, 25 children aged 9 to 14 were observed using Palenque in pairs for 45 to 60 minutes. The sessions were audiotaped and observational notes were kept by researchers. The available features in the prototype included virtual travel in two speeds, with revised arrow icons to facilitate turns and feedback; a you-are-here map; several pan/tilts with a dynamic compass; the camera and album (with two text input formats for testing); the first half of a motion video overview with C.T.; a preliminary "magic flashlight"; and the museum glyph room with Terry's audio narration. Our basic research questions were: How do children use and understand the major features, such as explore, museum, camera, album, map, and pans? How appealing are the motion video and audio, especially the characters? How effective is the joystick as an interface device? What kinds of "help" do children need? How effective are the interface conventions, such as the menu bar, icon panel, and cursor control? Some of the children's comments were as follows:

"Hey, we're walking . . . can we bump into anything? Are we going to crash?"

"I liked being able to control where you're going, to listen and walk around, to find out about glyphs . . ."

"Most games aren't about learning, this is fun learning--you help yourself learn."

In general, we found that real characters, motion video, and high-quality audio were among the most unique and appealing features of Palenque. The C.T. and Terry characters were "real people" whom the children liked having as guides and companions ("I've never seen a real person on a disc before"). The joystick conventions were mastered in a very short time by all the children (at the most it took several minutes of use, usually with no help from the researcher). The challenge of mastering the joystick conventions was the source of much of the game-like feel of Palenque. The extension cord on the joystick allowed children to sit a comfortable four or five feet from the screen. Requests for help usually were for information about various icons and menu bar options and how to get the cursor or make selections with the cursor, although children usually figured these things out by themselves when asked to try by the researchers.

The results of this formative evaluation led to many recommendations for modifications to the design. These modifications included such things as revising the turns so that users can step through leading turns rather than being led through automatically; allowing for exiting from the video overview; highlighting images in the museum glyph and rainforest rooms that can be selected for further information; allowing for on/off control of museum audio narration; reassigning the joystick buttons so that "map" is available as an icon on the screen; adding a white glove to the cursor hand so that it does not look like a "flying chicken"; revising the "go back" icon from a gesturing fist to the words "go back"; providing a mode-switching delay prompt; and allowing for scrolling through text.

The second phase II formative evaluation study. For the second formative evaluation study in phase II, eight 12-year-old children were observed using Palenque in pairs for four 60-minute sessions over a 4- to 6-week period. For the second two of the four research sessions, the children were given a structured activity in the form of a hypothetical archeologist's logbook, to be completed by using the Palenque system.

The sessions were audiotaped, observational notes were kept by researchers, and videotapes were recorded directly from the system (without a camera). The available features in the Palenque prototype included all of the features available in the first phase II study, with revisions suggested by the first study, plus three motion video overviews; ambient audio in explore mode; a "jump" map feature; motion video travel tips; motion video question/answer segments; the rainforest room "symphony" game; information zooms; on/off control of audio narration; and a revised museum menu.

Our basic research questions were: How appealing and comprehensible are the new Palenque features and options? How will children's interactions with the system change with extended sessions and a structured activity with explicit goals to guide their information seeking? The following discussion may give an idea of how well children were able to understand and use the range of interactive options available to them:

Child 1: Let's see what's over there (they jump with jump map).

Child 2: What's that temple in front of us?

Child 1: Ask CT. (They select CT travel tips icon.) It's the Temple of the Sun.

Child 2: Which one is it on the map?

Child 1: I don't know. Let's try the eyes, we can look around (they select the pan).

Child 2: Oh, look, we're smack dab in the middle of lots of temples. See (pointing to the map), here's the Temple of the Sun.

Child 1: Let's (jump) over there. I don't think we've been there.

In general, we found that children who had spent four hours with the system were still eager to come back and continue playing with it. The introduction of a simple "scavenger hunt" game (the archeologist's logbook) promoted great interest in and involvement with nearly every aspect of the system. The new features, including the video overviews, the "jump" map, the ambient audio, the motion video travel tips, and the rainforest symphony, were found to be useful, engaging, and informative.

As with the first formative evaluation study in phase II, the second study led to several recommendations for revisions to the Palenque design. These included such things as revising the jump map to make the image larger and more detailed; allowing for many more album pages; revising the means of accessing the overviews; eliminating the "pop-and-drop" feature of some icons; making the "turn-around" arrow an icon panel option; revising ear and movie camera icons; programming additional ambient audio, such as crickets on the site and footsteps; and eliminating text input via a "dynamo labeler" by using only the "soft" keyboard.

SUMMARY

The Palenque research and development project involved concurrent and iterative processes of design, research, production, and programming over the course of a 2-year time frame. Since our goal was to produce research prototypes rather than products, we perceived our mission to be one of experimentation in many areas, including the development of design conventions that reflected our chosen pedagogical biases, content and theme development, interface design, production techniques, and technical implementation. For this reason our collective research efforts in the areas listed above were the essence of the project rather than by-products or activities conducted after product completion.

By creating and researching a series of prototype discs and software, we were able to use the reactions of child users to catch design problems early, before they became major problems that we could not afford to spend the time or money to revise. Thus, the ongoing efforts of the formative researchers served to inform the efforts of the designers, producers, and programmers. By observing children representative of the target audience actually using the successive Palenque prototypes, the formative researchers were able to bring reactions from "real world" child informants to the design and development process. In this way, the creative hunches and intuitions of the designers, producers, graphic artist, and programmers were confirmed, modified, or disconfirmed relatively early in the development process as an ever-more appealing and comprehensible product for the target audience emerged.

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